GEOTECHNICAL ENGINEERING

TECHNICAL MEMORANDUM

FOR

ALTERNATIVES SELECTION

SUTTER BASIN, CALIFORNIA

Prepared By:

U.S. Army Corps of Engineers

Sacramento District

Geotechnical Branch

Levee Safety Section

January 2013

1.0 INTRODUCTION

This technical memorandum presents the geotechnical recommendations for screening of the draft array of alternatives for the Sutter Feasibility Study. These recommendations are intended to facilitate the selection of the final array of alternatives. As a result, the recommendations of this report are general and not site-specific, though each reach or segment recommendation is adjusted for large scale understanding of local conditions. Additionally, construction considerations were provided to the Civil Design section including typical design sections, haul and staging, construction sequencing, and borrow. This technical memorandum was prepared not using the Class 3 (feasibility level) analysis to develop seepage and stability mitigation measures (i.e. finite element seepage analysis or limit-equilibrium slope stability calculations). Instead, engineering judgment and experience on local projects was utilized for this Class 4 (reconnaissance level) analysis.

2.0 EVALUATION

This section presents the evaluation of the site conditions based on previous reports and studies, which provides the basis upon which the conclusions and recommendation are developed for the fix-in-place seepage measures.

2.1 Existing Condition Report

The Corps existing condition report indicates that pervasive underseepage concerns exist through the Sutter Feasibility Study area. Each reach has existing conditions where design criteria are not met for embankment geotechnical requirements (i.e. underseepage and stability). Breach failure before overtopping has happened three times during the life of this levee system (1909, 1911, and 1955) near Shanghai Bend, just south of Yuba City; the 1955 breach resulted in 38 fatalities. Without seepage control measures, the system will be subject to failure at less-than-overtopping loading conditions in the future. Levee modifications to the levee systems of the Yuba Basin on the opposite side of the Feather River, including Reclamation District 784 and the City of Marysville levees, have improved or are in the process of improving adjacent systems. Historically, at least one levee system on the Feather River has failed during each major flood during the last century.

2.2 External Document Review

Previous work for this project includes studies done by the local sponsors, the State of California Department of Water Resources and the Sutter Butte Flood Control Agency. This work was reviewed and utilized as part of the basis of our evaluation of the existing conditions , and used to develop the conclusions and recommendations presented for the Sutter basin Feasibility Study. These reports indicate that the levees of the Sutter Basin, including the east (left) levee of the Sutter Bypass from Wadsworth Canal to the Feather River, and the Feather River west (right) levee from Thermolito Afterbay Dam to the Sutter Bypass (see Map Plate 1), do not meet steady-state stability criteria for underseepage. The extent to which each reach fails to meet design criteria varies, but without exception, each reach has locations that do not meet underseepage criteria, often in multiple locations.

2.3 Key Assumptions

The following assumptions were used in the evaluation of the existing conditions (including for a potential ring levee around Yuba City, bypass and setback levees.) and for the analyzed alternatives.

- Levees will be modified or constructed considering seepage control or stability measures to provide embankment performance in accordance with USACE criteria for the entire levee system.
- Seepage and stability mitigation will be provided by construction of a cut-off wall along the entire system for all alternatives. Alternative selections are not based on a choice of seepage or stability mitigation measure. Selection of different mitigation measures such as seepage berms, relief wells, or cut-off walls along each reach is considered a design refinement and will be addressed in PED. Cutoff walls are less impactful to the environment and do not require the acquisition of real estate. The cost of soil-bentonite (SB) cutoff walls is competitive with berm construction.
- The exception to cutoff walls as seepage control mitigation measures are:

  Existing Relief Well Systems: used to the maximum extent possible in the reaches south of Yuba City at Shanghai Bend and Abbot Lakes/Star Bend.

  Seepage and Stability Berms: used in the northern reach near Thermalito Afterbay. The sponsor had previous indicated an interest and using gravel from the Oroville Goldfields dredger tailings to facility environmental mitigation. The presence of this gravel very close to the levee makes berm construction highly cost-effective in this area.

- Fix-in-place levee modifications have adequate subsurface geotechnical data for the development of feasibility level alternatives. For ring, setback, and bypass levees, there is no geotechnical subsurface data meeting the needs of a feasibility study. In order to develop feasibility recommendations that provide a reasonable basis for comparing alternatives, the structural measures for existing levees and new levees should ideally have a similar level of detail. This would best be achieved by having subsurface information and loading conditions developed to the same level of detail for new and existing levees. Since this is not possible without subsurface data on the ring, bypass and setback levee measures, a parametric approach was used. This approach was based only on a generalized understanding of the subsurface condition in Sutter and Butte counties, combined with past experience on fix-in-place and setback construction projects in the area (Yuba Basin).

- The parametric approach uses the maximum and minimum expected value concept. For example, design of a cutoff wall used estimates of the minimum and maximum expected depth and percentage of reach length requiring seepage control. After the maximum and minimum values were chosen, they were used to guide the selection of expected value. The median value was not used directly. These values were provided to civil designer so that quantities could be developed.
- New levees founded on older alluvium and located away from depressions, ditches or canals will likely require less seepage control (e.g. cutoff walls, seepage berms, etc) by percent of length.
- New levees will require more seepage control by percentage of length if the levee is taller (e.g. 8 feet or more) and less if it is shorter (e.g. 8 feet or less).
- For existing and new levees, deep cutoffs requiring specialized technology (e.g. deep soil mixing, jet grouting, etc) were considered design refinements and are not recommended at the feasibility level. It is expected that the reaches requiring the use of these methods will be short (e.g. bridge abutments or major utility crossing which may be left in place, etc). The increased cost of deep soil mixing (DSM) at $25 per square foot versus SB cutoff walls using slurry methods and excavators at $12 per square foot is significant; however, the percentage of the reaches is likely less than one percent of the entire project length. If long reaches requiring deep seepage control were encountered, the design level determination would most likely be the utilization of seepage using seepage berms or relief wells in lieu of cutoff walls.
- For areas where levee modification is required, including the addition of seepage control or stability mitigation, the resulting levee after construction will provide 1V:2H landside and 1V:3H waterside slopes and a 20-ft crest width.
- O&M easements for existing levees will be provided in the design of reaches requiring modification to not less than that prescribed by the current O&M manual. Additional O&M should be required to 15 or 20 ft of the landside to when feasible.
- Vegetation removal for ETL 1110-1-571 compliance will require at a minimum, removal of all non-compliant vegetation on the upper two-thirds of the waterside of the levee, the crest, landside slope and the existing landside easement.(if less than 15 feet, than a flooding easement will be required at least 15 feet from the landside toe free of woody vegetation)
- Seismic evaluation will be performed later in the Feasibility Study process, but seismic considerations are not considered to have a significant impact in alternative selection. Seismic analyses will be performed only to evaluate the extent of the damages but the levee alternatives will be not be affected by the seismic evaluation.
- A levee design template will be used by the civil and cost engineers to develop quantities based on inputs from this geotechnical engineering report. This template was developed by URS, and takes input for several key factors of a levee modification design (e.g. existing levee height and crest width, new depth of cutoff wall or width of seepage berm) and provides a parametric cost estimate for the levee segment for which this template is applied. The typical sections used are provided in the plates for Typical Drawing in this report.

3.0 CONCLUSIONS

The following geotechnical engineering conclusions are based on the evaluation of the subsurface conditions identified along the levees part of the Sutter basin and on the past performance of these levee and of the levees east site of Feather River. These conclusions are based heavily on engineering judgment which is guided strongly by experience in the local region and knowledge of the local soils.

3.1 General Conclusions for Fix-in-Place Alternatives

Based on the results of seepage and stability modeling, the existing levee system fails seepage design criteria within every reach, typically within multiple subreaches, and at a range of water surface profiles. The existing levee system fails to meet seepage and stability to varying degrees through the system, and underseepage mitigation in every reach is required to varying degrees.

3.2 Conclusions by Structural Segment

The conclusions are presented in clockwise order beginning with the Wadsworth Canal at the East/West Interceptor and progressing along the Sutter Bypass and Feather River to Thermalito Afterbay. Structural measure designations were developed by the Sutter PDT, and are broken down by geotechnical reach for the fix-in-place alternatives.

3.2.1 Wadsworth Canal (S7J)

The levee in this reach is approximately 20 ft in height (as measured from the landside toe to crest) at the downstream end, and the upper one-half of the segment, the levee is less than 7 feet tall, dropping to 3 feet at the upstream connection to the interceptor canals. A one-half mile long, 30 to 60 ft deep centerline soil-cement-bentonite (SCB) cutoff wall was constructed in this segment by the Corps near the downstream connection with the Sutter Bypass. Exploration performed by the State of California as part of their levee evaluation show that upstream of the cutoff wall, borings indicate sand layers covered by a thin impervious blanket or next to the surface which may require seepage control. Considering the adequate existing cutoff wall, the underseepage concerns upstream of the cutoff wall, and the lack of height of the levee upstream, a seepage control consisting of a seepage cut-off wall is recommended along approximately 25% of the segment. Based on the geotechnical conditions and of the existing cut-off wall, the depth varies between 20 and 50 feet, with an average depth of 40 ft.

3.2.2 Sutter Bypass (S7I)

The geotechnical and geomorphologic data provided by the State of California for the levee evaluation studies were used to evaluate the existing conditions and to recommend the mitigation alternatives. Exploratory borings and cone penetrometer testing (CPT) spaced at 1000 ft intervals, a long history of general past performance issues, and a series of seepage control measures of unknown quality and performance (toe drains, small seepage berms) indicate that additional seepage mitigation is required. The geology of this area consists of shallow basin deposits overlying hard pan layers. The general direction of geologic trend of soil deposits is roughly perpendicular to the levee, meaning a high frequency of small sand deposits is likely. The borrow pit cut through the hardpan layer near the waterside levee toe for construction of the existing levee creates a direct seepage connection to underlying sand layers. These factors indicate this levee has seepage concerns. Seepage cut-off wall is recommended for 100% of the reach, the depths of positive cutoff walls being relatively shallow (30 ft depth) but vary as much as 20 to 50 ft.

3.2.3 Sutter Bypass (S7H)

Borings and CPTs spaced at 1000 ft intervals, a long history of general past performance issues, and a series of seepage control measures of unknown quality and performance (toe drains, small seepage berms) indicate that additional seepage mitigation is required. The geology of this area consists of shallow basin deposits overlying hardpan clay layers. The general direction of geologic trend of soil deposits is roughly perpendicular to the levee, meaning a high frequency of small sand deposits is also likely and not easily detected by 1000-ft spaced borings. This reach contains Gilsizer Slough which is the active overbank flow channel from the Feather River to the west. The borrow pit cut through the hardpan layer near the waterside levee toe to construct the existing levee creates a direct seepage connection to underlying sand layers. These factors indicate this levee has seepage concerns and combined with the borings at Gilsizer Slough the cutoff wall may be deeper than other reaches of the Sutter Bypass. Seepage cut-off wall is recommended for 100% of the reach, the depths of positive cutoff walls relatively shallow (30 ft depth) but vary as much as 20 to 75 ft.

3.2.4 Sutter Bypass (S7G)

Borings and CPT spaced at 1000 ft intervals, a long history of general past performance issues, and a series of seepage control measures of unknown quality and performance (toe drains, small seepage berms) indicate that seepage mitigation is required. The geology of this area consists of shallow basin deposits overlying hardpan layers. The general direction of geologic trend of soil deposits is roughly perpendicular to the levee, meaning a high frequency of small sand deposits is likely. The borrow pit cut through the hardpan near the waterside levee toe for construction of the existing levee creates a direct seepage connection to underlying sand layers. These factors indicate this levee has seepage concerns. The levee height in this reach is the tallest of the entire Sutter Bypass. Therefore, seepage cut-off wall is recommended for 100% of the reach, the depths of positive cutoff walls being relatively shallow (30 ft depth) but vary as much as 20 to 50 ft.

3.2.5 Feather River (S7F)

The levee in this reach is tall (20 plus ft), and irrigation ditches are excavated near the landside levee toe. Borings and CPTs indicate shallow sand layers and thin to moderate blanket thicknesses that may lead to seepage sand boils. Seepage cut-off walls are recommended for 75% of the reach, the depths of positive cutoff walls to being moderately deep, 50 ft, but vary as much as 20 to 75 ft.

3.2.6 Feather River (S7E)

The levee in this reach is tall (20 plus ft), and has irrigation ditches excavated near the landside toe. Borings indicate deep sand layers and thin to moderate blanket thicknesses that may lead to high gradients and sand boils, however portions of the reach have deep clay foundations. A portion of this reach has existing relief wells. Seepage cutoff walls are recommended for 25% of the reach, and relief well collection system on additional 25% of the reach length. We expect depths of positive cutoff walls to be moderately deep, 65 ft, but vary as much as 20 to 75 ft.

3.2.7 Feather River (S7D/S5D)

The levee in this reach is tall (20 plus ft), and has irrigation ditches excavated near the landside toe. Borings indicate shallow and deep sand layers and thin to moderate blanket thicknesses that may lead to high gradients at the levee toe; however, portions of the reach have deep clay foundations. A portion of this reach has existing relief wells. Seepage cutoff walls is recommended for 50% of the reach and an additional 15% will require relief well collection system modification. We expect depths of positive cutoff walls to be moderately deep, 65 ft, but vary as much as 20 to 75 ft.

3.2.8 Feather River (S7C)

The levee in this reach is tall (20 plus ft), and has irrigation ditches excavated near the landside toe. Borings indicate shallow and deep sand layers and thin to moderate blanket thicknesses that may lead to high gradients at the levee toe. Based on these considerations, seepage cut-off wall is recommended for 75% of the reach. The depths of positive cutoff walls should be moderately deep, 65 ft, but vary as much as 20 to 75 ft.

3.2.9 Feather River (S7B)

The levee in this reach variable in levee height from as little as 3 feet to as much as 15 ft, and has ditches excavated along the landside toe, including the major irrigation Sutter Butte Canal. Borings indicate shallow sand layers that may lead to high gradients at the levee toe for parts of this reach. Seepage control may be required as part the method in which the Sutter Butte Canal will be addressed. Based on these considerations, seepage cutoff walls are necessary for 100% of the reach, and we expect depths of positive cutoff walls to be moderately deep, 65 ft, but vary as much as 20 to 75 ft.

3.2.10 Feather River (S7A)

The levee in this reach varies in height from 3 to 4 feet to 18 ft. Borings indicate shallow sand layers and thin to moderate blanket thicknesses that may be seepage paths. The levee may require modification to address insufficient geometry in the Goldfields portion. Based on these considerations, seepage mitigation is recommended for 50% of the segment, seepage and stability mitigation for 25% of the segment and stability mitigation is required for 25% of the reach. Seepage berms and stability berms may be the best mitigation here, due to the sponsor's interest in using local borrow sources.

3.3 General Conclusions for New Levees (Setback Levees, Ring Levees and Cross Levees)

Based on experience with new levees, including setback levees previously constructed within the basin (e.g. Star and Shanghai Bends in Levee District 1, and the Feather River Setback Levee in Reclamation District 784), new levees will require a cutoff wall for some percentage of length, though typically to a lesser extent than existing levees. This is likely due to the distance from active river channels, and the lower likelihood of founding the levee on poor foundation conditions. Therefore we conclude that new levees far from the active river system will need seepage mitigation measures at a lower rate per unit length.

3.4 Conclusions by Reach

The conclusions for new levee segments are presented in clockwise order beginning with the Wadsworth Canal at the East/West Interceptor and progressing along the Sutter Bypass and Feather River to Thermalito Afterbay.

3.4.1 Sutter Bypass Setback Levee (S9I)

Seepage mitigation is assumed to be similar to the associated segment of the existing Sutter Bypass levee. Increased seepage path length by moving the levee back from the waterside borrow pit may result in a lower percentage of cutoff walls, but it will not eliminate the need for seepage control.

3.4.2 Sutter Bypass Setback Levee (S9H)

Seepage mitigation is assumed to be similar to the associated segment of the existing Sutter Bypass levee. Increased seepage path length by moving the levee back from the waterside borrow pit may result in a lower percentage of cutoff walls, but it will not eliminate the need for seepage control.

3.4.3 Sutter Bypass Setback Levee (S9G)

Seepage mitigation is assumed to be similar to the associated segment of the existing Sutter Bypass levee. Increased seepage path length by moving the levee back from the waterside borrow pit may result in a lower percentage of cutoff walls, but it will not eliminate the need for seepage control.

3.4.4 Lower Feather River Setback Levee (S11)

Depending on the final alignment, seepage control may be reduced below levels on the Sutter Bypass and south Feather River segment, due to the presence of an intact waterside blanket.

3.4.5 Star Bend Setback Levee (S12)

Based on borings for the Star Bend Setback Levee, seepage mitigation is required through the entire reach to depths of approximately 40 to 60 ft.

3.4.6 Yuba City, Ring Levee – South (S4) and J-Levee - South (S6)

Ring levees are assumed to be relatively short, and if they are constructed in areas with an intact blanket on the waterside of the levee (likely in this area based on experience), a lesser percentage of cutoff walls is expected. Seepage control is likely for one-third of this alignment.

3.4.7 Yuba City, Ring Levee – West (S4), J-Levee – West Lower (S6) and J-Levee – West Upper (S6)

Ring levees are assumed to be relatively short, and if they are constructed in areas with an intact blanket on the waterside of the levee (likely in this area based on experience), a lesser percentage of cutoff walls is expected. Seepage control is likely for one-third of this alignment.

3.4.8 Yuba City, Ring Levee – North (S4)

Ring levees are assumed to be relatively short, and if they are constructed in areas with an intact blanket on the waterside of the levee (likely in this area based on experience), a lesser percentage of cutoff walls is expected. Seepage control is likely for one-third of this alignment.

3.4.9 Northern Feather River Setback Levee (S10)

There is more uncertainty with the foundations conditions in this reach. Deep coarse-grained materials are known to exist in the Biggs area, so seepage mitigation is likely to be extensive. Also, this area was an overflow area for the Feather River during the 1800's and early 1900's.

This indicates that shallow sand layers and a high-frequency of sand lenses or stringers are likely to be present. Seepage mitigation is likely for 100% of the reach.

4.0 RECOMMENDATIONS

Recommendations for typical design sections (templates), new levees, construction staging and hauling, borrow, and structural segment-specific recommendations are provided within this section.

4.1 Typical Design Sections

Typical design sections are provided in the Plates section of this memorandum. These include all typical designs, which correspond to the templates used by URS in their parametric analysis performed for this project.

4.2 New Levee Design

All levees designs shall provide 1V:3H landside and waterside slope with a 20 ft crest width and 15 ft waterside and 20 ft landside O&M easements. Table 3 provides typical levee corridor widths, and Typical Detail Plates 6 and 7 provide the geometrical relationships of new levees with and without SB slurry walls.

4.3 Construction Staging and On-Site Hauling

Levee modification projects typically require long linear haul routes for on-site construction and staging areas situated at periodic intervals. For long slurry wall projects, we recommend that 2 acre sites every 2500 linear feet of levee. Typically slurry wall construction requires bentonite slurry ponds, and typically these are located about every one-half mile. The bentonite slurry is pumped to the active excavation site through pipes. Major staging areas are also required. Major staging areas are where equipment maintenance, employee parking and job trailers are located. Assume 5 acres for a typical 5 mile long slurry wall project. Multiple concurrent cutoff wall projects may require a large central staging area.

4.4 Borrow

We recommend that 15 miles as a typical haul distance for borrow. Values as low as 10 or as high as 30 may be reasonable, but 15 miles is conservative, and higher values are not warranted considering that suitable material can be typically found within the basin. It is likely that borrow will become cost prohibitive if not obtained within this distance, primarily due to air quality impacts. A conservative shrinkage percentage should be used. We recommend 15% at the feasibility level.

4.5 Seepage and Stability Mitigation by Structural Measure

These recommendations are presented as ranges (i.e. remediate reach X with a cutoff wall along 50 to 100% of the reach with a depth ranging from 20 ft to 60 ft). The measures are presented in a clockwise organization beginning on the Wadsworth Canal and progressing through the Sutter Bypass and Feather River to Thermalito Afterbay.

4.6 Fix-in-Place Measures

This section presents recommendation for seepage and stability mitigation, presented by fix-in—place structural segment.

4.6.1 Wadsworth Canal

Construct a centerline SB cutoff wall for 25% of the reach, to an expected depth of 40, with a range of typical depths of 20 to 50 ft.

4.6.2 Sutter Bypass (S7I)

Construct a centerline SB cutoff wall for 100% of the reach, to an expected depth of 30 ft, with a range of typical depths of 20 to 50 ft.

4.6.3 Sutter Bypass (S7H)

Construct a centerline SB cutoff wall for 100% of the reach, to an expected depth of 30 ft, with a range of typical depths of 20 to 75 ft.

4.6.4 Sutter Bypass (S7G)

Construct a centerline SB cutoff wall for 100% of the reach, to an expected depth of 30 ft, with a range of typical depths of 20 to 50 ft.

4.6.5 Feather River (S7F)

Construct a centerline SB cutoff wall for 75% of the reach, to an expected depth of 50 ft, with a range of typical depths of 20 to 75 ft.

4.6.6 Feather River (S7E)

Construct a centerline SB cutoff wall for 25% of the reach, to an expected depth of 40 ft, with a range of typical depths of 20 to 75 ft.

4.6.7 Feather River (S7D/S5D)

Construct a centerline SB cutoff wall for 50% of the reach, to an expected depth of 50 ft, with a range of typical depths of 20 to 75 ft. Modify existing relief well systems by reconfiguration of the collection system, including lower well head rise height from 4 above grade to 1 ft below grade for 15% of the reach for a total of 65% seepage mititgation.

4.6.8 Feather River (S5C)

Construct a centerline SB cutoff wall for 75% of the reach, to an expected depth of 65 ft, with a range of typical depths of 20 to 75 ft.

4.6.9 Feather River (S5B)

Construct a centerline SB cutoff wall for 100% of the reach, to an expected depth of 65 ft, with a range of typical depths of 20 to 75 ft.

4.6.10 Feather River (S5A)

Construct a seepage berm for 75% of the reach, to height of 5 ft and width of 12 ft. Construct a stability berm for 50% of the reach, with a height of 12 ft and top width of 12 ft. The resulting segment recommendation is for 50% of the segment to have a seepage berm only, 25% to have a stability berm only and 25% to have a combined seepage and stability berm.

4.7 Ring, Bypass and Setback Measures

This section presents recommendation for seepage control for new levees, presented by ring, bypass or setback levee structural segment.

4.7.1 Sutter Bypass Setback Levee (S9I)

Construct a centerline SB cutoff wall for 100% of the reach, to an expected depth of 35 ft, with a range of typical depths of 20 to 50 ft.

4.7.2 Sutter Bypass Setback Levee (S9H)

Construct a centerline SB cutoff wall for 100% of the reach, to an expected depth of 35 ft, with a range of typical depths of 20 to 50 ft.

4.7.3 Sutter Bypass Setback Levee (S9G)

Construct a centerline SB cutoff wall for 100% of the reach, to an expected depth of 35 ft, with a range of typical depths of 20 to 50 ft.

4.7.4 Lower Feather River Setback Levee (S11)

Construct a centerline SB cutoff wall for 50% of the reach, to an expected depth of 35 ft, with a range of typical depths of 30 to 70 ft.

4.7.5 Star Bend Setback Levee (S12)

Construct a centerline SB cutoff wall for 100% of the reach, to an expected depth of 65 ft, with a range of typical depths of 30 to 70 ft.

4.7.6 Yuba City, Ring Levee – South (S4) and J-Levee - South (S6)

Construct a centerline SB cutoff wall for 34% of the reach, to an expected depth of 35 ft, with a range of typical depths of 30 to 60 ft.

4.7.7 Yuba City, Ring Levee – West (S4), J-Levee – West Lower (S6) and J-Levee – West Upper (S6)

Construct a centerline SB cutoff wall for 34% of the reach, to an expected depth of 35 ft, with a range of typical depths of 30 to 60 ft.

4.7.8 Yuba City, Ring Levee – North (S4)

Construct a centerline SB cutoff wall for 34% of the reach, to an expected depth of 35 ft, with a range of typical depths of 30 to 60 ft.

4.7.9 Northern Feather River Setback Levee (S10)

Construct a centerline SB cutoff wall for 100% of the reach, to an expected depth of 75 ft, with a range of typical depths of 20 to 75 ft.

5.0 REFERENCES

- State of California, Department of Water Resources Urban Levee Geotechnical Evaluations Program, Phase 1 Preliminary Geotechnical Evaluation Report, Sutter Study Area, March 2008, URS
- State of California, Department of Water Resources Urban Levee Geotechnical Evaluations Program, Phase 1 Geotechnical Data Report, Sutter Study Area, November 2008, URS
- State of California, Department of Water Resources Urban Levee Geotechnical Evaluations Program, Supplemental Geotechnical Data Report, Sutter Study Area, April 2010, URS
- Sutter Butte Flood Control Agency, Pre-Design Formulation Report, West Feather River Project, August 2011, prepared by HDR, Wood Rodgers, URS and MHM
- Sutter Butte Flood Control Agency, 60% design submittal package, West Feather River Project, January 2012, prepared by HDR, Wood Rodgers, URS and MHM

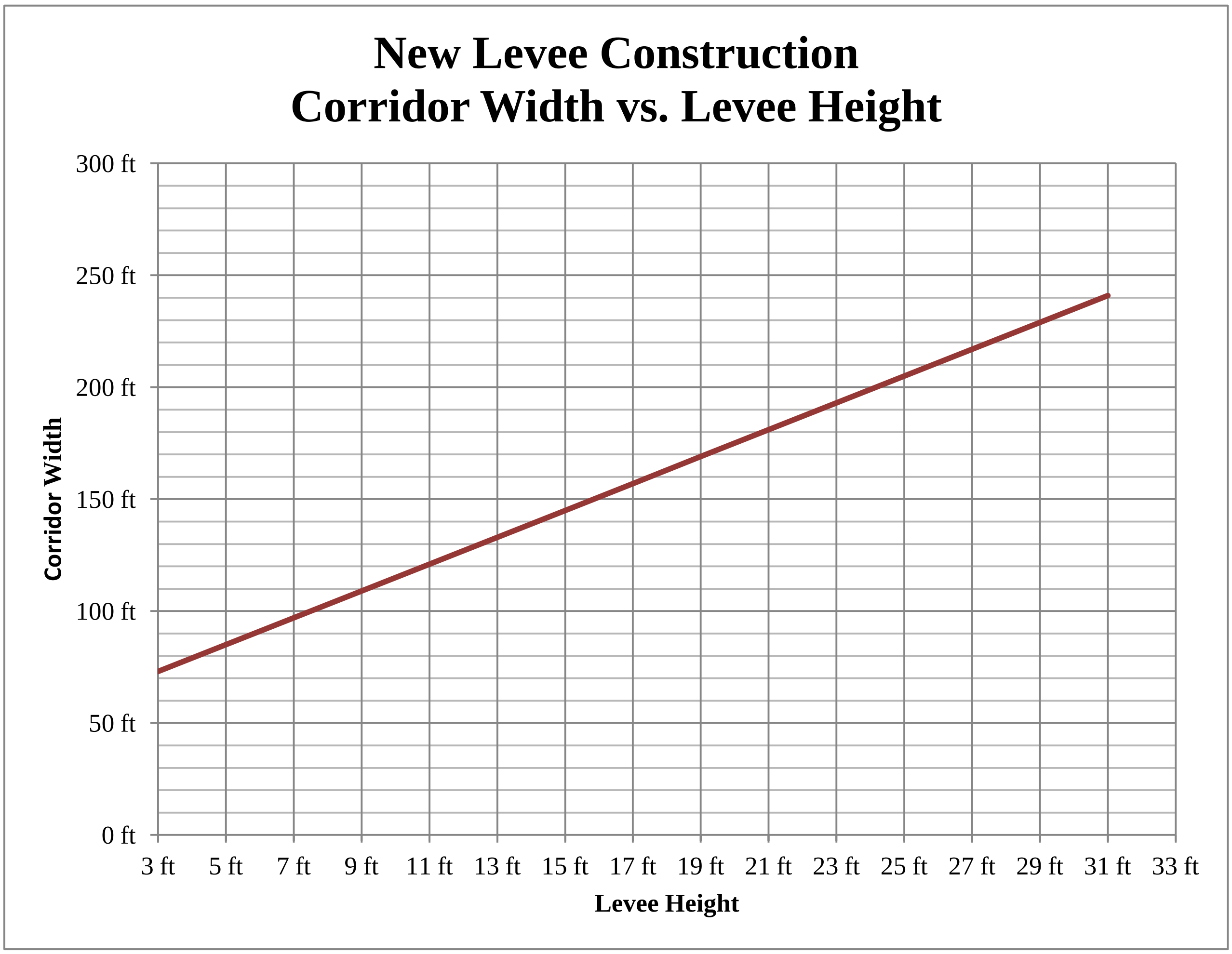
TABLES

Table 1, Summary of Recommendations by Structural Element of the Existing Levee System							
Structural Element	Name	PLM	PLM	Feature	% Length	Depth/Height	Width
S7J	Wadsworth Canal	0	4.66	SB CL Cutoff wall	25	40 ft (20 to 50)	N/A
S7I	Sutter Bypass	4.4	12.65	SB CL Cutoff wall	100	30 ft (20 to 50)	N/A
S7J	Sutter Bypass	12.65	14.35	SB CL Cutoff wall	100	30 ft (20 to 75)	N/A
S7H	Sutter Bypass	14.35	22.37	SB CL Cutoff wall	100	30 ft (20 to 50)	N/A
S7F	Feather River	MA03 0.00 LD1 0.00	MA 5.19 LD1 2.70	SB CL Cutoff wall	75	50 ft (20 to 75)	N/A
S7E	Feather River	LD1 2.70	LD1 6.20	SB CL Cutoff wall	25	65 ft (20 to 75)	N/A
S7D	Feather River	LD1 6.20	LD1 10.5	SB CL Cutoff wall[1]	50	65 ft (20 to 75)	N/A
S5D/S4-EAST	Feather River	LD1 10.5	LD1 16.65	SB CL Cutoff wall[1]	50	65 ft (20 to 75)	N/A
S5C	Feather River	LD9 0.00	LD9 5.50	SB CL Cutoff wall	75	65 ft (20 to 75)	N/A
S5B	Feather River	LD9 5.50| MA16 0 MA7 0.00	LD9 6.24 MA16 4.69 MA7 1.80	SB CL Cutoff wall	100	65 ft (20 to 75)	N/A
S5A	Feather River	MA7 1.80 MA7 HB 0.00	MA7 12.07 MA7 HG 0.08	Stability Berm Seepage Berm	50 75	12 ft 150 ft	12 ft 5 ft

[1] Modifications to the existing relief well system are required per section 4.6.7.

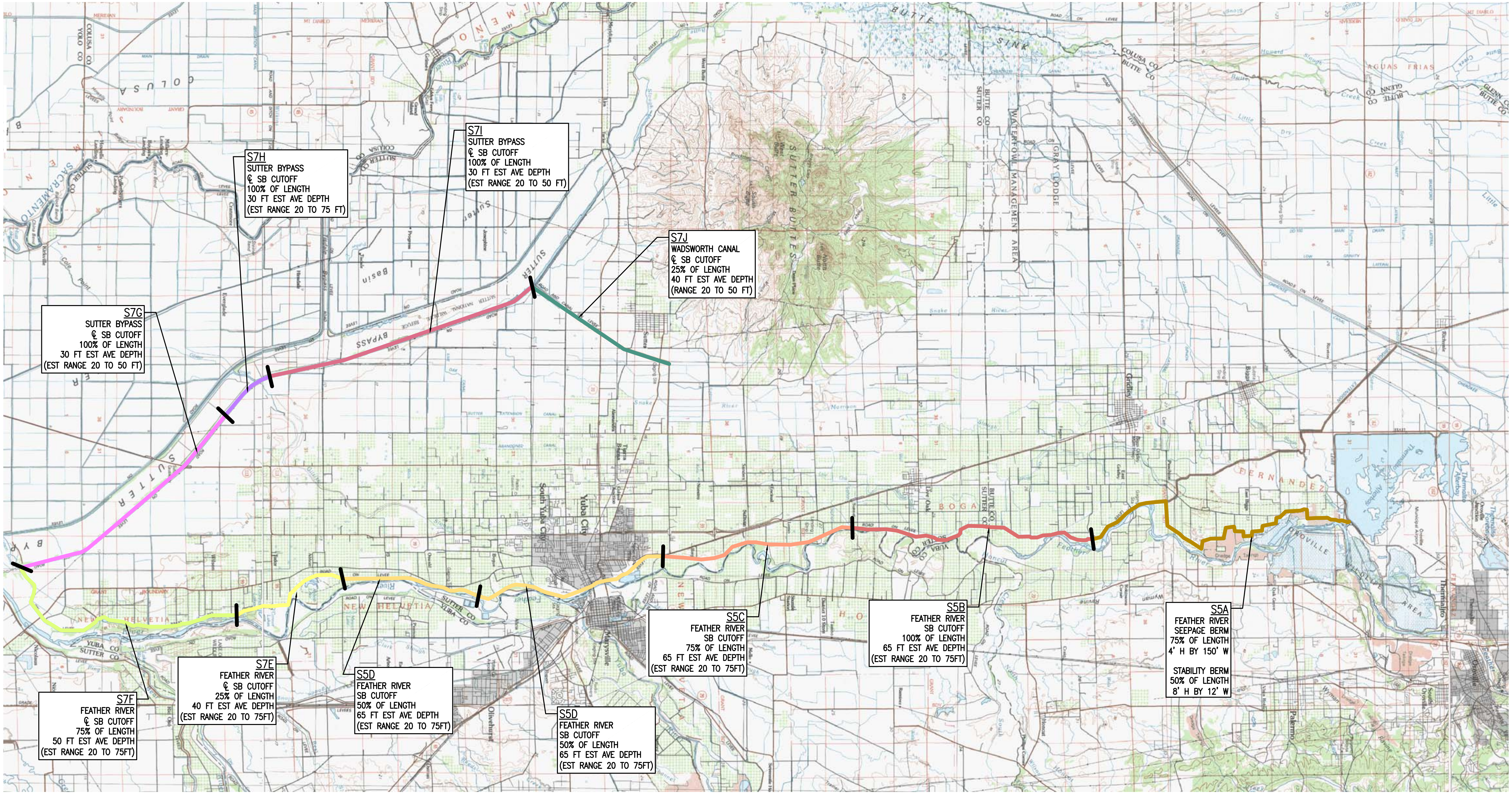
Table 2 Summary of Recommendations for Segments of Ring Levees, Setback Levees, and Bypass Levees							
Structural Element	Name	PLM	PLM	Feature	% Length	Depth/Height	Width
S9I	Sutter Bypass Setback	N/A	N/A	SB CL Cutoff wall	25	35 ft (20 to 50)	N/A
S9H	Sutter Bypass Setback	N/A	N/A	SB CL Cutoff wall	25	35 ft (20 to 50)	N/A
S9G	Sutter Bypass Setback	N/A	N/A	SB CL Cutoff wall	25	35 ft (20 to 50)	N/A
S11	Sutter Bypass and Feather River Confluence Setback Levee	N/A	N/A	SB CL Cutoff wall	50	35 ft (20 to 50)	N/A
S12	Star Bend Setback	N/A	N/A	SB CL Cutoff wall	100	65 ft (30 to 70)	N/A
S4-SOUTH **S6-SOUTH**	Yuba City J-Levee	N/A	N/A	SB CL Cutoff wall	34	35 ft (20 to 60)	N/A
S4-WEST **S6-WEST**	Yuba City J-Levee	N/A	N/A	SB CL Cutoff wall	34	35 ft (20 to 60)	N/A
S6-WEST-UPPER	Yuba City J-Levee	N/A	N/A	SB CL Cutoff wall	34	35 ft (20 to 60)	N/A
S4-NORTH	Yuba City J-Levee	N/A	N/A	SB CL Cutoff wall	34	35 ft (20 to 60)	N/A
S10	Northern Feather River Setback Levee	N/A	N/A	SB CL Cutoff wall	100	75 ft (20 to 50)	N/A

TABLE 3, Levee Geometrical and O&M Requirements for New Levees										
Levee Height	Landside O&M	Landside Slope	Landside Length	Landside Height	Crest Width	Waterside Slope	Waterside Length	Waterside Height	Waterside O&M	Corridor
3 ft	20 ft	1V:3H	9 ft	3 ft	20 ft	1V:3H	9 ft	3 ft	15 ft	73 ft
5 ft	20 ft	1V:3H	15 ft	5 ft	20 ft	1V:3H	15 ft	5 ft	15 ft	85 ft
7 ft	20 ft	1V:3H	21 ft	7 ft	20 ft	1V:3H	21 ft	7 ft	15 ft	97 ft
9 ft	20 ft	1V:3H	27 ft	9 ft	20 ft	1V:3H	27 ft	9 ft	15 ft	109 ft
11 ft	20 ft	1V:3H	33 ft	11 ft	20 ft	1V:3H	33 ft	11 ft	15 ft	121 ft
13 ft	20 ft	1V:3H	39 ft	13 ft	20 ft	1V:3H	39 ft	13 ft	15 ft	133 ft
15 ft	20 ft	1V:3H	45 ft	15 ft	20 ft	1V:3H	45 ft	15 ft	15 ft	145 ft
17 ft	20 ft	1V:3H	51 ft	17 ft	20 ft	1V:3H	51 ft	17 ft	15 ft	157 ft
19 ft	20 ft	1V:3H	57 ft	19 ft	20 ft	1V:3H	57 ft	19 ft	15 ft	169 ft
21 ft	20 ft	1V:3H	63 ft	21 ft	20 ft	1V:3H	63 ft	21 ft	15 ft	181 ft
23 ft	20 ft	1V:3H	69 ft	23 ft	20 ft	1V:3H	69 ft	23 ft	15 ft	193 ft
25 ft	20 ft	1V:3H	75 ft	25 ft	20 ft	1V:3H	75 ft	25 ft	15 ft	205 ft
27 ft	20 ft	1V:3H	81 ft	27 ft	20 ft	1V:3H	81 ft	27 ft	15 ft	217 ft
29 ft	20 ft	1V:3H	87 ft	29 ft	20 ft	1V:3H	87 ft	29 ft	15 ft	229 ft
31 ft	20 ft	1V:3H	93 ft	31 ft	20 ft	1V:3H	93 ft	31 ft	15 ft	241 ft



PLATES

MAP PLATES



SUTTER BASIN

STUDY MAP SHOWING GEOTECHNICAL RECOMMENDATIONS BY REACH FOR FIX-IN-PLACE MEASURES

MEASURE NAMING CONVENTION
S = STRUCTURAL MEASURE
5, 7, ETC = DESIGNATION INDICATING ASSOCIATED ALTERNATIVE
H, G, I = GEOTECHNICAL FIX-IN-PLACE REACH DESIGNATION

SCALE IN FEET

0 7500 15000 30000

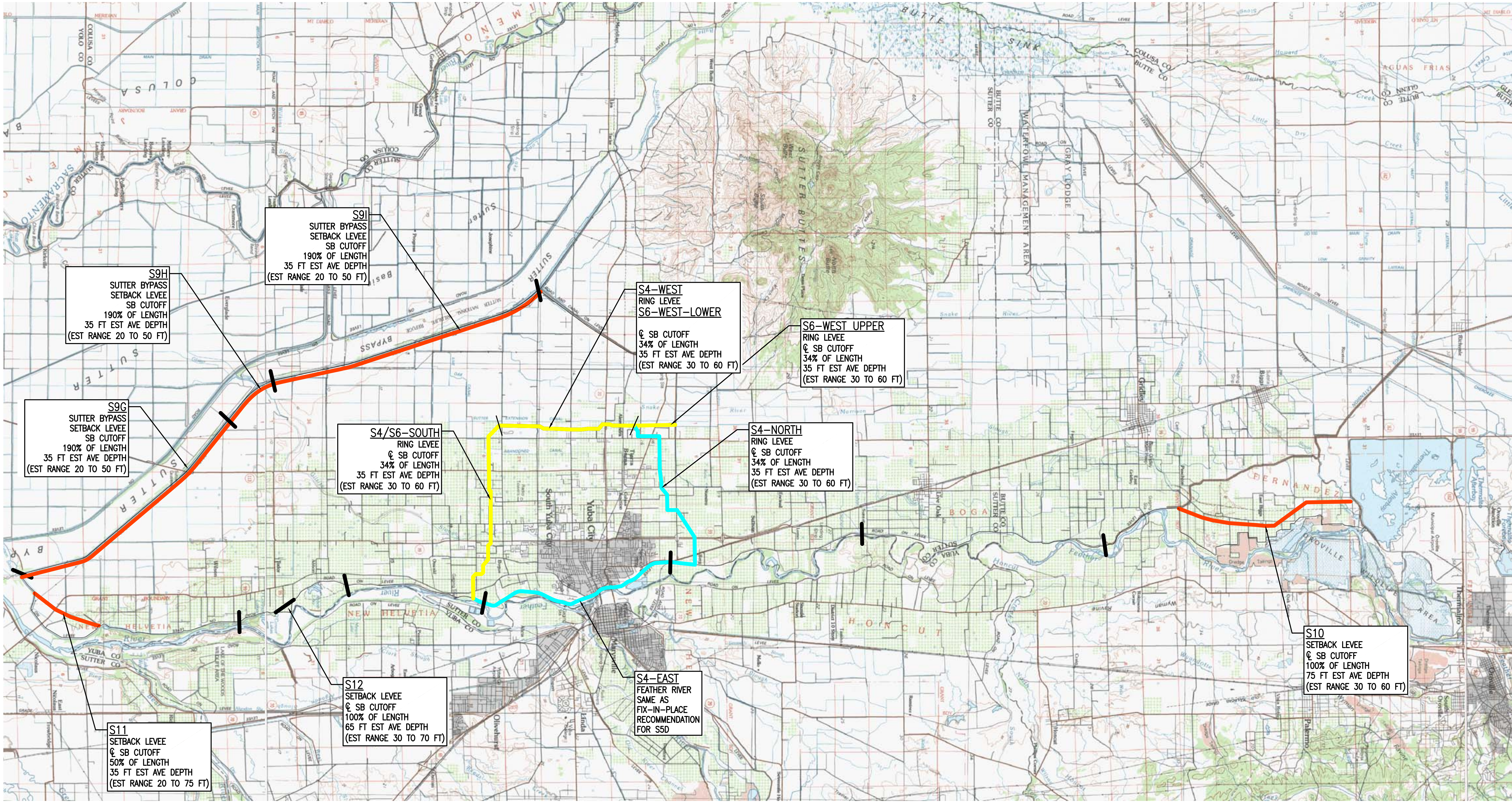
DEPARTMENT OF THE ARMY
SACRAMENTO DISTRICT
CORPS OF ENGINEERS
SACRAMENTO, CALIFORNIA

SUTTER AND BUTTE COUNTIES CALIFORNIA

SUTTER FEASIBILITY STUDY
TECHNICAL MEMORANDUM FOR ALTERNATIVE EVALUATION

GEOTECHNICAL RECOMMENDATIONS FOR FIX-IN-PLACE MEASURES

DATE:	SCALE:	
5/30/12	1" = 15000'	MAP 1



SUTTER BASIN

STUDY MAP SHOWING GEOTECHNICAL RECOMMENDATIONS BY REACH FOR RING, SETBACK, AND BYPASS MEASURES

MEASURE NAMING CONVENTION
S = STRUCTURAL MEASURE
5, 7, ETC = DESIGNATION INDICATING ASSOCIATED ALTERNATIVE
H, G, I = GEOTECHNICAL FIX-IN-PLACE REACH DESIGNATION

SCALE IN FEET
0 7500 15000 30000

DEPARTMENT OF THE ARMY
SACRAMENTO DISTRICT
CORPS OF ENGINEERS
SACRAMENTO, CALIFORNIA

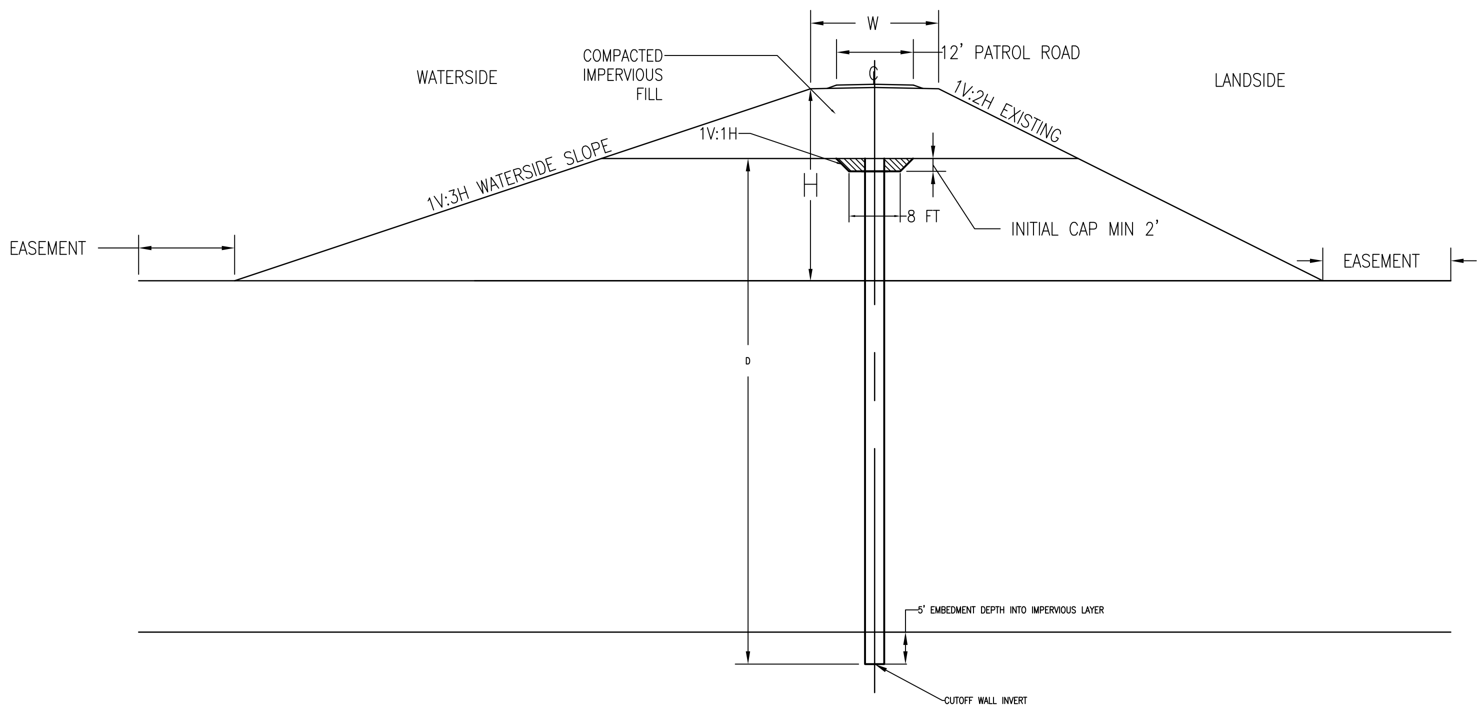
SUTTER AND BUTTE COUNTIES CALIFORNIA

SUTTER FEASIBILITY STUDY
TECHNICAL MEMORANDUM FOR ALTERNATIVE EVALUATION

GEOTECHNICAL RECOMMENDATIONS
RING, SETBACK AND BYPASS ALTERNATIVES

DATE:	SCALE:	
5/30/12	1" = 15000'	MAP 2

TYPICAL DETAIL PLATES



SUTTER BASIN

LEVEE REHABILITATION WITH CENTERLINE
SOIL-BENTONITE CUTOFF WALL
SLURRY METHOD

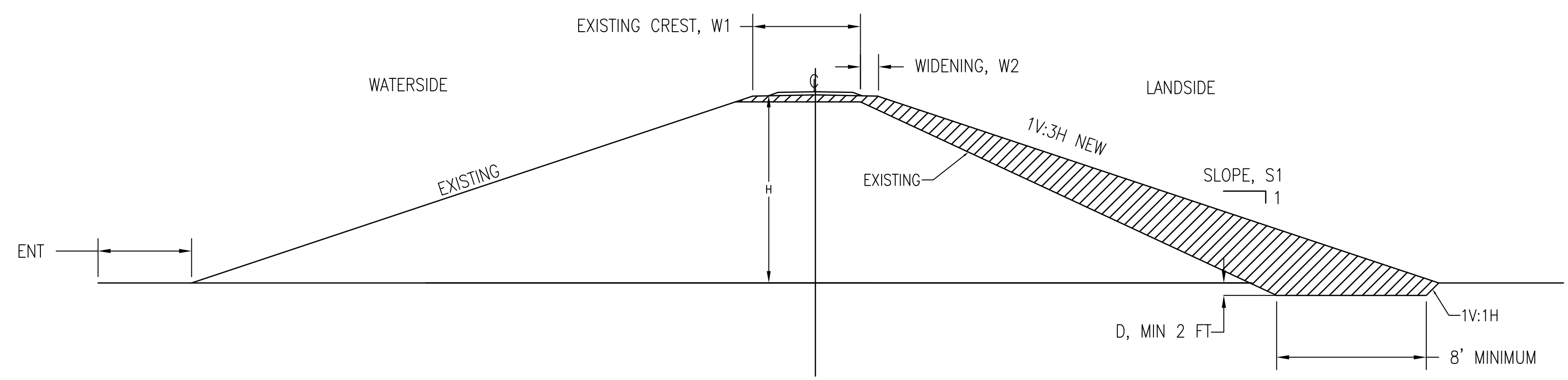
PARAMETERS:
D, CUTOFF DEPTH
H, LEVEE HEIGHT
H1, DEGRADE HEIGHT

DEPARTMENT OF THE ARMY
SACRAMENTO DISTRICT
CORPS OF ENGINEERS
SACRAMENTO, CALIFORNIA

SUTTER AND BUTTE COUNTY CALIFORNIA

SUTTER BASIN
GEOTECHNICAL ENGINEERING
TECHNICAL MEMORANDUM
LEVEE REMEDIATION MEASURES
SB SLURRY METHOD CUTOFF WALL
TYPICAL SECTION

DATE:	SCALE:	
5/30/12	NO SCALE	TYP 1



SUTTER BASIN

LEVEE REHABILITATION

WIDENING AND SLOPE MODIFICATIONS

PARAMETERS:
D, KEY DEPTH
H, LEVEE HEIGHT
W1 EXISTING CREST WIDTH
W2, ADDITIONAL CREST
S1, SLOPE RUN PER 1' RISE

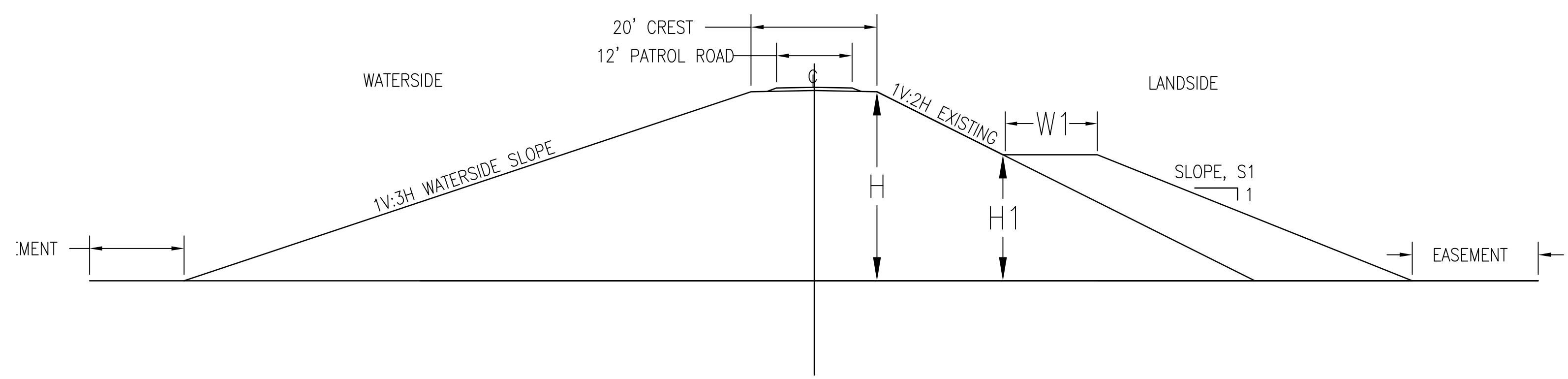
DEPARTMENT OF THE ARMY
SACRAMENTO DISTRICT
CORPS OF ENGINEERS
SACRAMENTO, CALIFORNIA

SUTTER AND BUTTE COUNTY — CALIFORNIA

SUTTER BASIN
GEOTECHNICAL ENGINEERING
TECHNICAL MEMORANDUM

LEVEE REMEDIATION MEASURES
WIDENING AND SLOPE MODIFICATIONS
TYPICAL SECTION

DATE:	SCALE:	
5/30/12	NO SCALE	TYP 2



SUTTER BASIN

LEVEE REHABILITATION WITH LANDSIDE STABILITY BERM

PARAMETERS:
H, LEVEE HEIGHT
H1, BERM HEIGHT
W1, BERM WIDTH
S1, SLOPE RUN PER 1' RISE

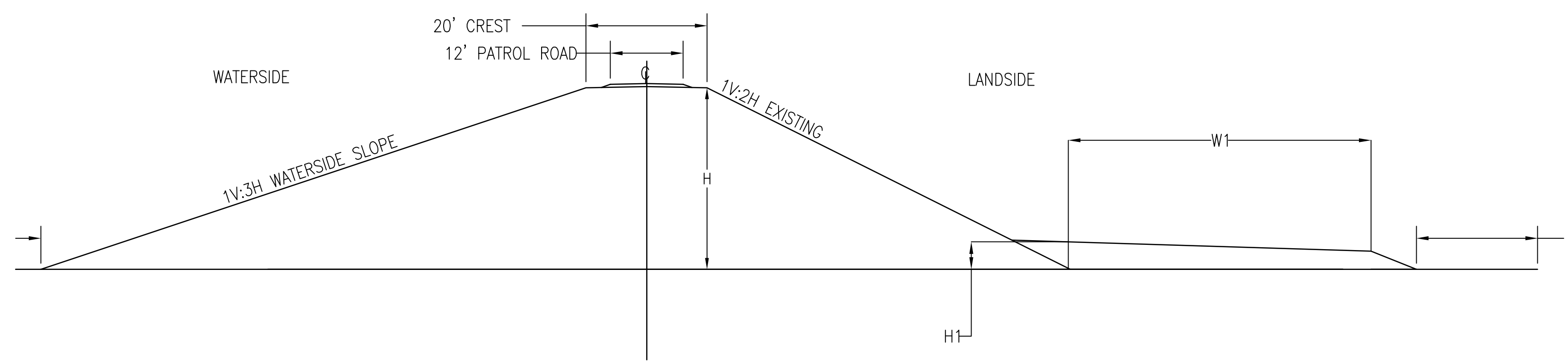
DEPARTMENT OF THE ARMY
SACRAMENTO DISTRICT
CORPS OF ENGINEERS
SACRAMENTO, CALIFORNIA

SUTTER AND BUTTE COUNTY CALIFORNIA

SUTTER BASIN
GEOTECHNICAL ENGINEERING
TECHNICAL MEMORANDUM

LEVEE REMEDIATION MEASURES
STABILITY BERM
TYPICAL SECTION

DATE:	SCALE:	
5/30/12	NO SCALE	TYP 3



SUTTER BASIN

LEVEE REHABILITATION WITH SEEPAGE BERM

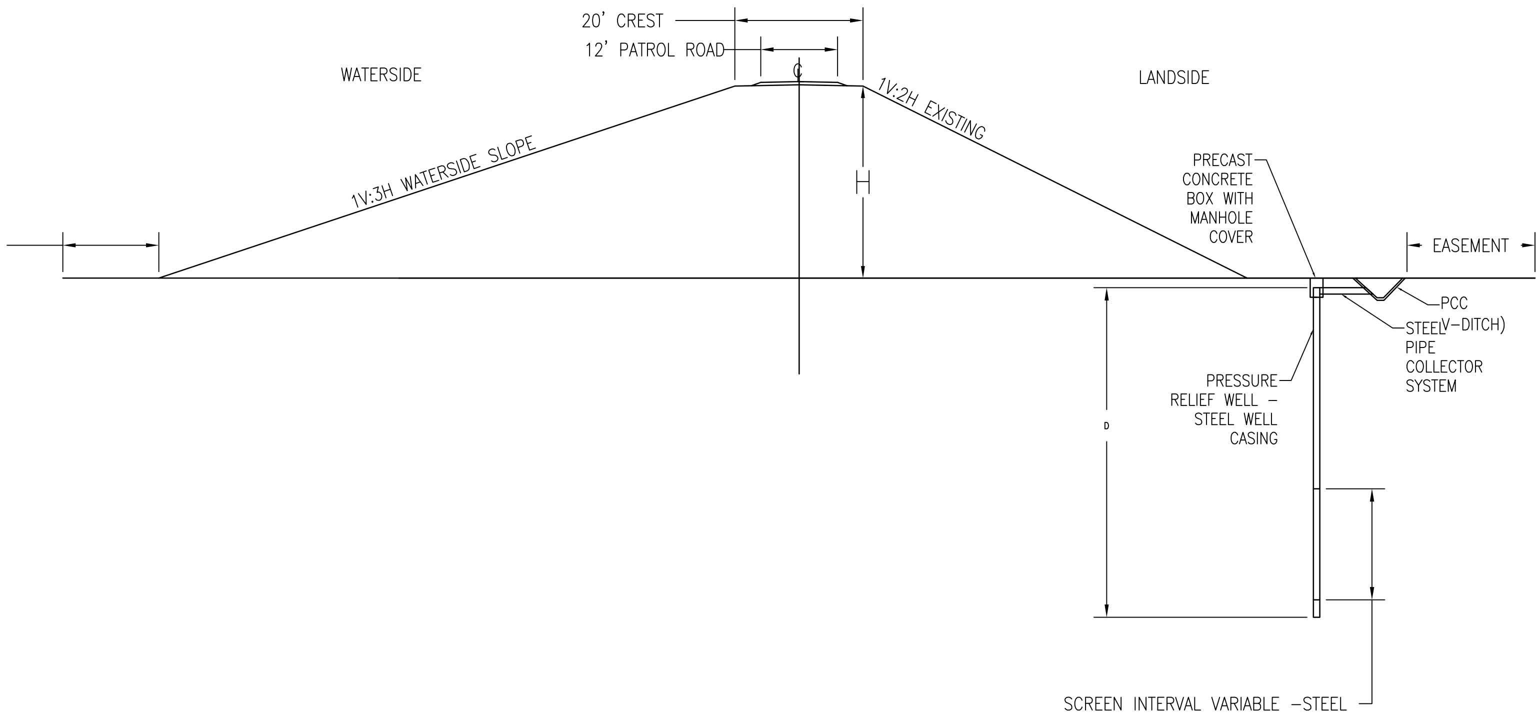
PARAMETERS:
H1, BERM HEIGHT
H2, BERM WIDTH
H, LEVEE HEIGHT

DEPARTMENT OF THE ARMY
SACRAMENTO DISTRICT
CORPS OF ENGINEERS
SACRAMENTO, CALIFORNIA

SUTTER AND BUTTE COUNTY CALIFORNIA

SUTTER BASIN
GEOTECHNICAL ENGINEERING
TECHNICAL MEMORANDUM
LEVEE REMEDIATION MEASURES
SEEPAGE BERM
TYPICAL SECTION

DATE:	SCALE:	
5/30/12	NO SCALE	TYP 4



SUTTER BASIN

LEVEE REHABILITATION WITH PRESSURE RELIEF WELLS AND COLLECTOR SYSTEM

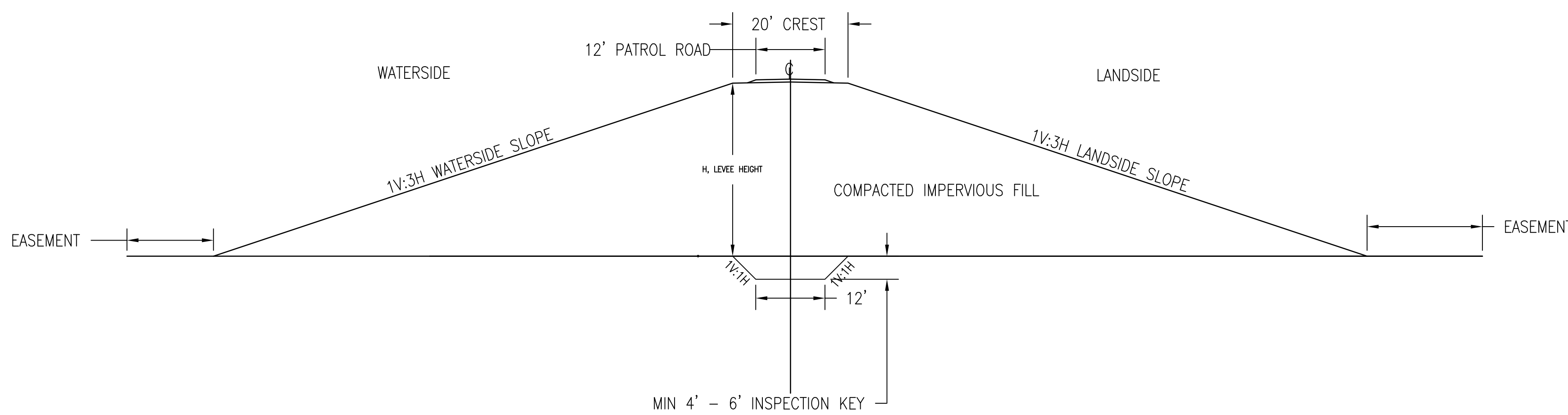
PARAMETERS:
D, WELL DEPTH
H, LEVEE HEIGHT

DEPARTMENT OF THE ARMY
SACRAMENTO DISTRICT
CORPS OF ENGINEERS
SACRAMENTO, CALIFORNIA

SUTTER AND BUTTE COUNTY CALIFORNIA

SUTTER BASIN
GEOTECHNICAL ENGINEERING
TECHNICAL MEMORANDUM
LEVEE REMEDIATION MEASURES
PRESSURE RELIEF WELLS
TYPICAL SECTION

DATE:	SCALE:	
5/30/12	NO SCALE	TYP 5



SUTTER BASIN

NEW LEVEE – NO SEEPAGE CONTROL

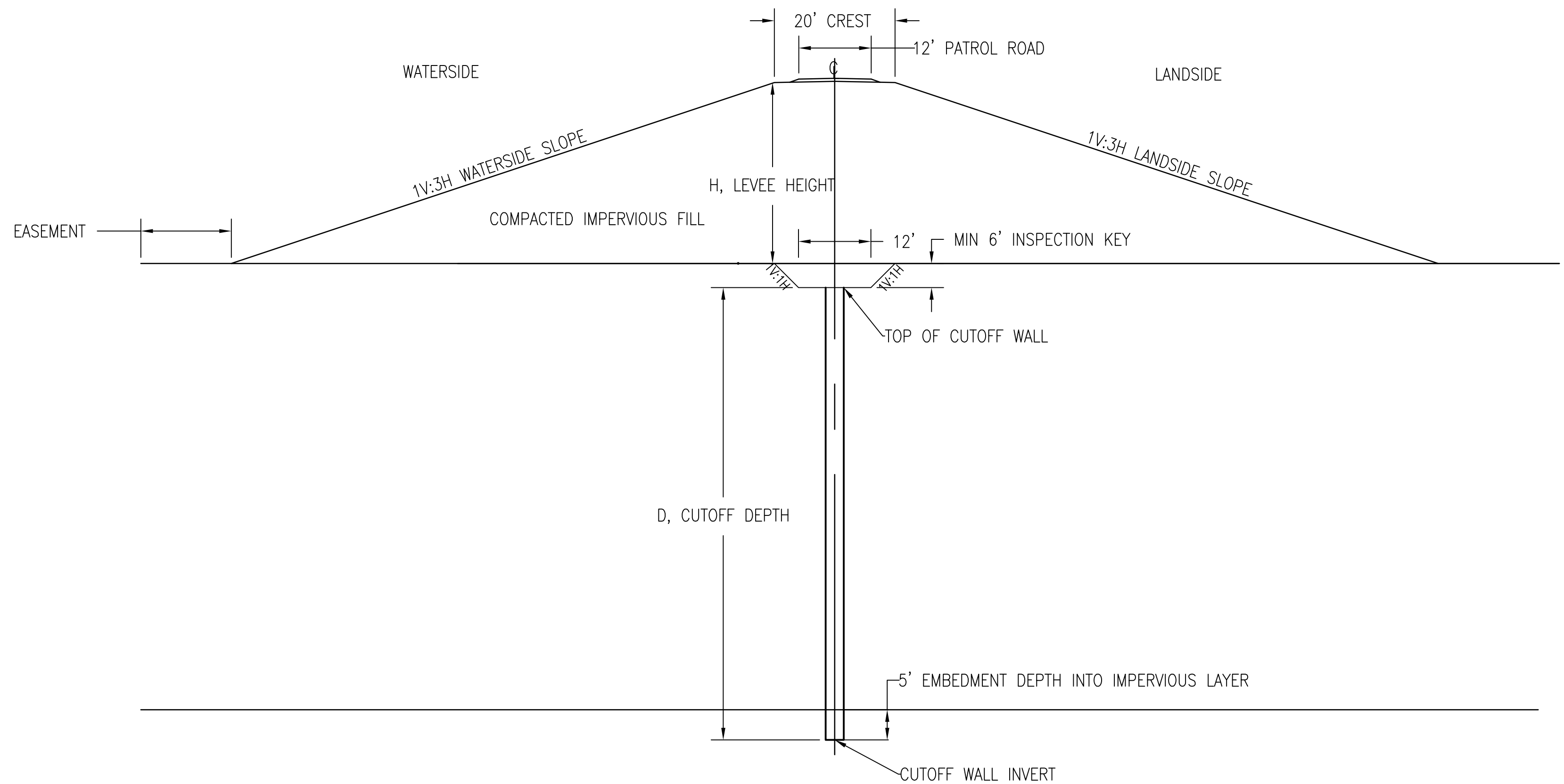
PARAMETERS:
H, LEVEE HEIGHT

DEPARTMENT OF THE ARMY
SACRAMENTO DISTRICT
CORPS OF ENGINEERS
SACRAMENTO, CALIFORNIA

SUTTER ABD BUTTE COUNTIES CALIFORNIA

SUTTER BASIN
GEOTECHNICAL ENGINEERING
TECHNICAL MEMORANDUM
NEW LEVEE CONSTRUCTION
NO SEEPAGE CONTROL
TYPICAL SECTION

DATE:	SCALE:	
5/30/12	NO SCALE	TYP 6



SUTTER BASIN

NEW LEVEE – SOIL–BENTONTITE SLURRY WALL

PARAMETERS:
D, WELL DEPTH
H, LEVEE HEIGHT

DEPARTMENT OF THE ARMY
SACRAMENTO DISTRICT
CORPS OF ENGINEERS
SACRAMENTO, CALIFORNIA

SUTTER ABD BUTTE COUNTIES — CALIFORNIA

SUTTER BASIN
GEOTECHNICAL ENGINEERING
TECHNICAL MEMORANDUM
NEW LEVEE CONSTRUCTION
SOIL–BENTONITE SLURRY WALL
TYPICAL SECTION

DATE:	SCALE:	
5/30/12	NO SCALE	TYP 7